Hybrid Insulators for Distribution Lines: Definitions, Advantages & Application Experience

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ABSTRACT

Extreme environmental or high pollution conditions such as those encountered in industrial, desert or coastal regions can lead to electrical activity on insulators, including current leakage. The polluted surface condition of an insulator in such regions can lead to flashovers and, ultimately, to power system outages. The need for reliable power networks, avoidance of blackouts and shutdown of grids due to frequent maintenance activities like grid washing, has led the insulator industry to react.

The majority of insulators currently in use around the world for power grids and distribution networks are porcelain, but the use of polymeric/composite insulators has been increasing rapidly. A combination of these technologies has emerged as a Hybrid Insulator Class.

The new class, Hybrid insulator, combines the advantages of a porcelain core (undisputed superiority of high mechanical strength, stability & longevity) with the excellent performance of silicone housings, and provides an ideal solution for use in highly contaminated service conditions.

In a recent past, there was not a standard defining classification and testing methodology for Hybrid insulators. This has resulted in manufacturers creating their own classification and test methods, independent from an agreed upon standard.

It opened the opportunity to manufacturers developing their own project and classification of Hybrid insulators. At this time, good and bad solutions were developed.

A new Standard from IEC brings definitions, test methods and acceptance criteria, so the IEC 62896, Hybrid insulators for a.c. and d.c. high-voltage applications, gave the opportunity to this article make a clear definition of Hybrid Insulator.

Over the past 15 years of manufacturer's experience with hybrid insulators, good results of R&D job in a partnership with a Brazilian Utility and a research Institute, allowed this article to bring also the good results and the application experience in the field with low voltage hybrid insulators.

Keywords: Hybrid insulators, Polymeric insulator, Composite insulators, HDPE pin insulator, Line Post insulators, Leakage Current, Low voltage power grids, Polluted Environment.

1- BACKGROUND & HISTORY

The problem of vandalism on railway catenary insulators in the 1970s led the UK to examine the use of plastic insulators to replace the porcelain insulators commonly used at the time. [1][2]. Pultruded epoxy resin bonded glass fibre rod using E-glass had been developed for the high voltage switchgear industry; this rod was used in the development of under bridge arm HV insulators for the 25kV catenary. At the time, these rods were available only in diameters of up to 25 mm. The tie and structural porcelain insulators typically had 70 mm core diameters, and portal post insulators up to 80 mm core diameters. To obtain similar mechanical properties in bending and compression it was necessary to use a glass fibre core of around 50 mm in diameter. These larger cores were not available in pultruded form without longitudinal electrical weaknesses [2].

It was proposed therefore to make polymeric housed insulators using cylindrical porcelain cores of the same core diameter and with the same end fittings as the existing porcelain insulators. This would ensure that they were identical in mechanical performance and part replacements for the existing porcelains [3] [4].

With this, the Hybrid insulator was born, combining the mechanical strength of porcelain and the hydrophobicity and resistance to impact damage of the polymeric housing.

2- INTRODUCTION

According to IEC 62896 [1], Hybrid insulators consist of an insulating core bearing the mechanical load, protected by a polymeric housing. The load is transmitted to the core by end fittings. Despite these common features, the materials used and the construction details employed by different manufacturers may be quite different. The core may be made of porcelain or glass material.

Currently in the market there are, unfortunately manufacturers using a composite insulator structure with a fiberglass core and porcelain head, which they classify as a hybrid insulator (Fig.1). This design incorporates all the weakness (fragile fracture, degradation, etc.) of the original composite designs.

Fig.1 - Advertising from internet of composite insulators with porcelain assembled in the top part (head) called as hybrid by the manufacturers

Hybrid insulators are used as overhead line, post or hollow core equipment insulators. In design testing, IEC 62217 [5] shall be applied for the polymeric housing and the interfaces between the core and the housing. For the core, the test standards for the respective ceramic product (IEC 60168 [6], IEC 60383 [7][8] and IEC 62155 [9]) shall be applied [1].

Some tests have been grouped together as "design tests", to be performed only once on insulators which satisfy the same design conditions. For all design tests of hybrid insulators, the common clauses defined in IEC 62217 [5] are applied. As far as practical, the influence of time on the electrical and mechanical properties of the components (core material, housing, interfaces etc.) and of the complete hybrid insulators has been considered in specifying the design tests to ensure a satisfactory lifetime under normally known stress conditions in service [1].

Polymeric housing materials that show the hydrophobicity transfer mechanism (HTM) are preferred for hybrid insulators. They are applied as a countermeasure against severe polluted service conditions. For the time being, no ageing or pollution tests have been developed for the verification of this property, but CIGRE Technical Brochure No. 442 is available for the evaluation of the retention of the hydrophobicity and the HTM of polymeric housing materials [10].

3- DEFINITION

According to IEC 62896 [1] hybrid insulator consists of a ceramic or glass core and a polymeric housing, equipped with one or more metal fittings

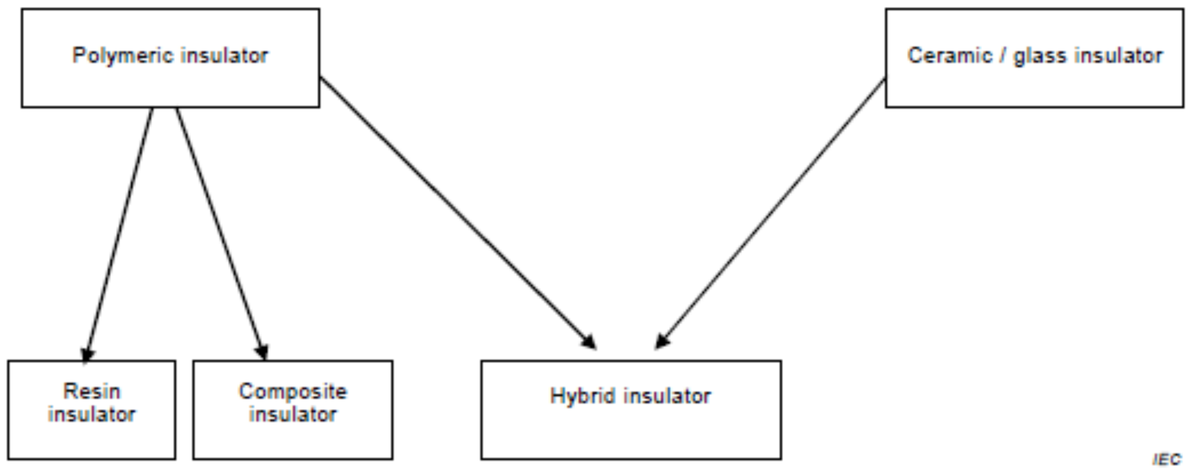

Fig. 2- IEC 62896 chart explaining hybrid definition [1].

Note 1 to entry: The mechanical functions are mainly characterized by the core, the electrical functions are mainly characterized by the polymeric housing. The housing may cover the core completely or partly. In the latter case the exposed portions of the ceramic core are usually covered by glaze.

The core of a hybrid insulator is the internal insulating part, consisting of porcelain or glass insulator which is designed to ensure the mechanical characteristics.

The housing is the external insulating part which is made of polymeric material providing necessary creepage distance and protecting the core from the environment.

The end fitting fixing device is the integral component or formed part of an insulator intended to connect it to a supporting structure, or to a conductor, or to an item of equipment, or to another insulator.

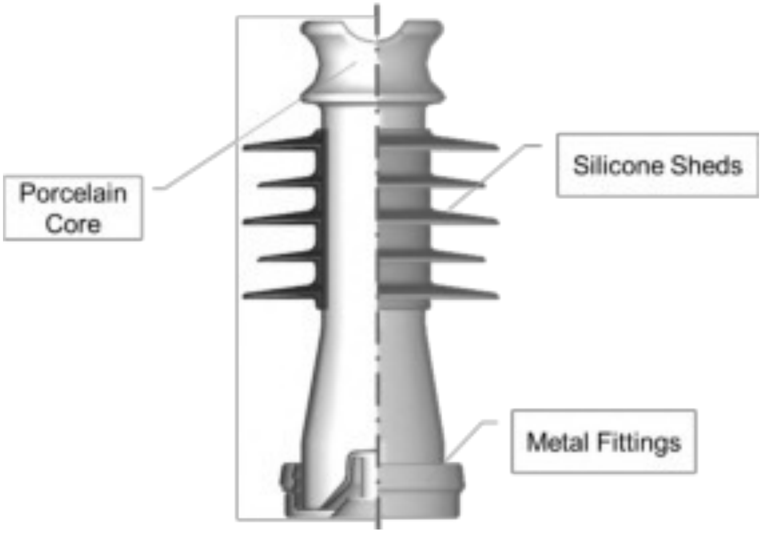

Fig. 3 - PPC Santana hybrid insulator.

4- COMPARING TECHNOLOGIES

4.1- Advantages of hybrid insulators over conventional porcelain insulators

The core is made by a simple extrusion process and this gives a low weight mechanical part with consistent mechanical properties compared to a shedded porcelain.

The polymeric housing offers protection to the core and more resistance to impact damage than the sheds of a conventional porcelain.

The Hybrid insulator is typically one-half to one-quarter of the weight of a conventional porcelain insulator, which reduces transport costs and transport/installation breakages and eases installation.

The use of a polymeric housing normally allows thinner sheds and greater creepage distances with improved long-term pollution flashover performance. In addition the hydrophobicity of the polymeric housing brings excellent performance and self-cleaning to work under polluted environment.

The polymeric housing protects the core from short circuit arc damage which can fracture conventional ceramic insulators [1].

4.2- Advantages of hybrid insulators over glass fibre cored insulators

It is common for composite insulators to first show dry band arcing or electrochemical damage on the insulation next to the end fittings. By leaving an exposed glazed porcelain band at this point, the partial discharges take place over the glazed porcelain surface, and not over a more vulnerable polymeric housing.

The core material is not susceptible to moisture ingress problems. If the housing is damaged, the porcelain core itself remains unaffected by moisture ingress.

They can be easily made as part replacements for conventional porcelain posts used in substations, switchgear and overhead lines.

The manufacturing processes are relatively much easier to control compared to making resin/glass fibre rod, and crimping on end fittings.

Post insulators can include the same lipped and grooved ends to accept OHL conductors that are used on conventional line posts [1].

4.3- Problems shared with polymeric insulators

Selection of appropriate housing material is very important to guarantee excellent field performance. Long-term stability such as UV weathering resistance, retention of hydrophobicity and tracking and erosion resistance must be considered.

Another aspect to be considered is forming an electrically stable interfacial seal between the housing and the glazed ceramic core. This is normally done with either a suitable material, an RTV Room Temperature Vulcanizing silicone material, or the housing may be “moulded in place” using appropriate coupling agents, as is done with resin glass cores [3].

The experience shows that, the best option is HTV High Temperature Vulcanizing Silicone (High pressure injection molding at high temperature) moulded directly on the porcelain surface.

The silicone housing is fully bonded onto the porcelain solid core, perfectly managing the “triple point” (fitting-silicone housing-porcelain core).

Thanks to the high pressure involved in this operation, the silicone housing adheres directly onto the fitting or the porcelain without the need for artificial sealing.

5- APPLICATION EXPERIENCE

Brazil has a densely populated coastline approximately 8.000km in length.

The salt polluted environment causes electrical problems for distribution utilities. Hybrid insulators have been used in these harsh coastal environments with very favourable results: reducing the need for maintenance and washing, fewer interruptions of energy and reduction of operating costs.

Hybrid insulators have also been tested in other countries and a variety of polluted conditions with very good performance results. In Chile, for example, in the desert area, thousands of porcelain Pin type insulators with a large protected creepage distance were replaced with Hybrid insulators, and have proven very effective.

In this section we will discuss the application results and field tests of a Utility located in the Northeast of Brazil, Neoenergia Group, which has a partnership with Lactec, a Brazilian R&D Institute.

5.1- R&D Neoenergia & Lactec

5.1.1 Description

At Pituba substation area, in Bahia State, which is located approximately 500m from the sea, a pilot network was built with a length of 15m and composed of four spaced poles.

Cables, insulators and crossarms were installed on the poles. Two lines were assembled in parallel using the same poles: a single-phase line operating at 34.5 kV, and another single-phase line operating at 13.8 kV.

Porcelain insulators and Hybrid insulators, both of the same pollution class level IV according to IEC 60815 [11], were installed in the pilot grid for the purpose of monitoring the leakage current. Fig. 4 (a) shows an overview of the pilot network before installation of the insulators.

Fig. 4 (b) shows the insulators installed on the lead wires to measure the leakage current. The metal pin of each insulator was connected to the grounding wire, and 1kOhm resistors were connected to the grounding connections.

Lactec developed a special instrument to measure the leakage current. The data was obtained through an Agilent data acquisition unit, model 34970A, and stored in a microcomputer. A 3G modem connected to the microcomputer allowed remote access via the internet.

Fig 4 – a – Pilot network.

Fig 4 – b – Insulators and connections.

5.1.2- The Pollution Problem

Fig. 5 shows the problem caused by the leakage current due to the salt pollution on the insulators. The cross arms are usually destroyed and the insulators become loose, causing electrical contacts and interruption of service in the lines, sometimes burning the cross arms.

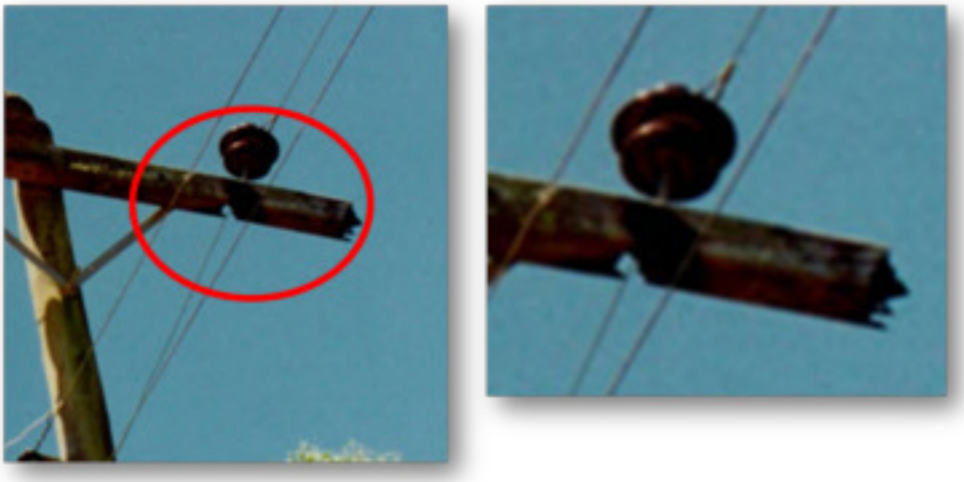

Fig. 5 – Leakage current and damage at cross arms in Bahia State - BR

5.1.3- The Results

The first observation got was the difference of hydrophobicity and the wet band area on the two different technologies, as can be noted on the Figure 6.

It is clear that on the Hybrid polymeric shed there are distinct, unconnected drops, indicating a highly hydrophobic surface. On the surface of the porcelain insulator, however, a wet continuous band was detected, indicating a hydrophilic surface.

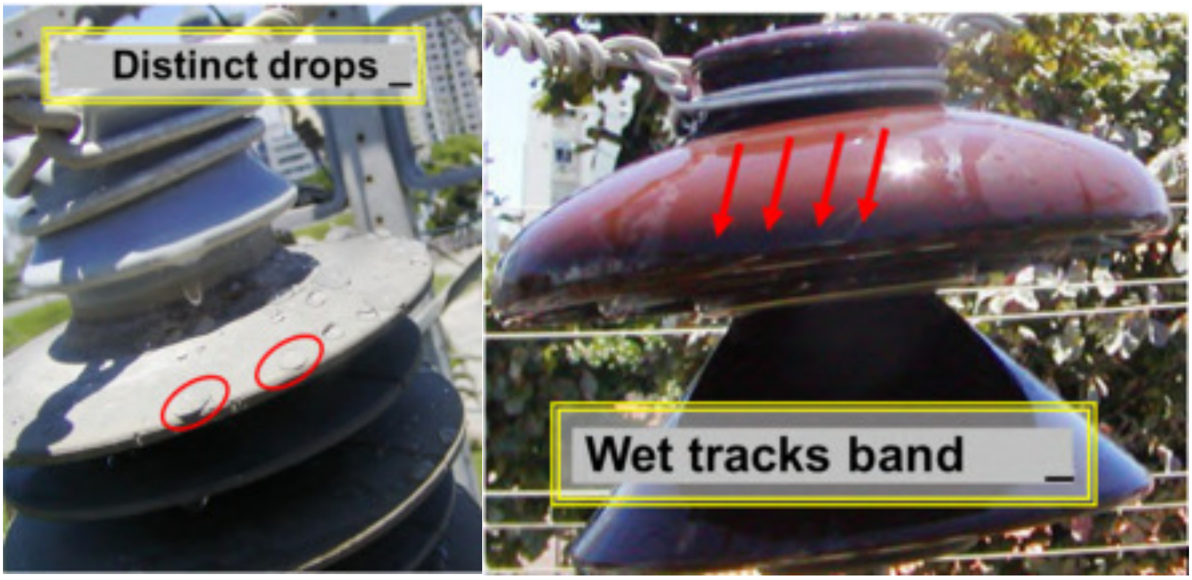

Fig. 6 – Hydrophobicity and the wet band area

After 1,5 years, the data of leakage current versus time shows better performance of the Hybrid insulator than the Anti-fog design Porcelain insulator at the same leakage distance Level IV according to IEC 60815 [11]. Fig. 7 shows the data results.

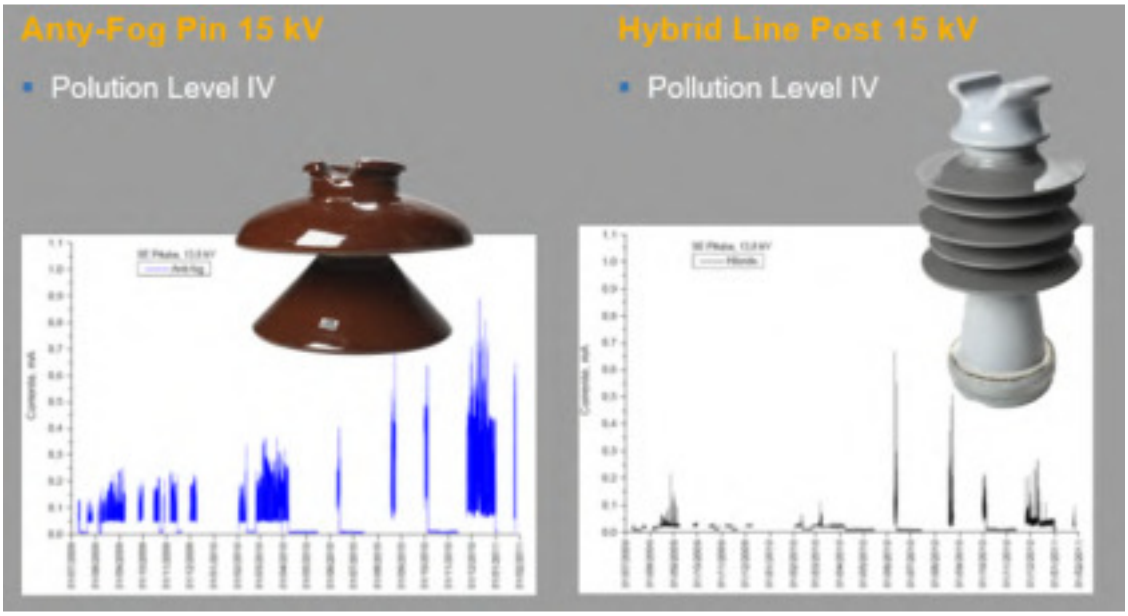

Fig. 7 – Data of leakage current versus time during 1,5 years of field test in Bahia State - BR

5.2- Other Application Experiences

With more than 10 years of experience and 125,000 Hybrid insulators sold and utilized in several countries including Brazil, Chile, Peru, Philippines and New Zealand, we have seen the same successful application of Hybrid insulators used in various polluted environments as in the salt polluted coastal areas of Brazil and in desert zones.

In the Northeast of Brazil, the local utility used to wash the grid at least twice per year; the use of Hybrid insulators has eliminated the need for washing. The records show these insulators in service in a severely salt polluted environment in grids of 15kV, 25kV and 35kV for over ten years, maintaining reasonable hydrophobicity and not in need of replacement.

In a Chilean desert area, the local utility used Pin type insulators (Fig. 8), with a large protected creepage distance (fog type), and experienced many problems with leakage current due to the sand deposition internally in the sheds. To combat this problem, more than 50,000 hybrid insulators were installed, and the results have been very positive. In this case also, the insulators have been in use for more than ten years with reasonable retention of hydrophobicity and no need of replacement.

Fig. 8 – Pin type fog insulator according Chilean Utility standard based in ANSI 55-7

6- CONCLUSION

Hybrid insulators are probably the most important innovation in LV overhead lines and Substations in the last decades. Despite their simple solution of combining a porcelain core and polymeric sheds/housing, a successful design requires the use of quality materials.

The housing should be a long-life Hydrophobic component which, according to the best practices and field experience, should utilize a silicone HTV (High Temperature Vulcanizing) designed with specific additives (fillers) to protect the silicone from erosion. These fillers – typically ATH (Alumina Tri Hydrate) fillers – must be incorporated in the polymer in specific minimum quantities to be effective.

The core should be a continuous and single piece of porcelain made of high-strength alumina oxide (C130 according to IEC 60672), thereby avoiding the aging of material and electro corrosion problems of the insulator, and taking advantage of the high mechanical strength, unique stability, and long time performance of this material.

Hybrid insulators combine the advantages of a porcelain core (undisputed superiority of high mechanical strength, stability & longevity) with the excellent performance of silicone housings, which provides an ideal solution for use in highly contaminated service conditions [12].

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